STAND DIVERSITY IN THE DINARIC FIR-BEECH FORESTS

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Abstract

Data from forest research and permanent sampling plots were used to quantify stand structure and forest diversity in uneven-aged Dinaric silver fir and beech forest at the level of forest management unit. The study examined the indicators that are expected to be used in the monitoring of biodiversity and the favourable conservation status of forest habitat types in Natura 2000 sites. By comparing the present and past stand structures, it was possible to establish the developmental dynamics of the stands and the changes of structure indices of the forest stands on the 2-hectare research plots in the last 50 years. We adopted the indicators for the assessment of biotic and stand structure diversity based on tree species composition, stand densities, mean DBH and coefficient of variation, species and DBH-based Shannon's index, spatial mingling and size differentiation of trees on the permanent sampling plots. The indicators confirmed stand structural diversity in four forest management classes of uneven-aged Dinaric fir-beech forests in the Leskova dolina (valley) of the Sneznik-Javorniki high Karst region. Continuous forest inventory and the presented indicators of stand structure and diversity may potentially represent the framework for the monitoring of the favourable conservation status of forest habitat types.

Key words: stand structure, stand diversity monitoring, indicators, uneven-aged fir and beech stands, *Abies alba* Mill., *Fagus sylvatica* L.

SESTOJNA RAZNOVRSTNOST V DINARSKIH JELOVO-BUKOVIH GOZDOVIH

Izvleček

Na podlagi podatkov gozdarskih raziskovalnih ploskev in stalnih vzorčnih ploskev smo ocenili zgradbo in pestrost v dinarskih jelovo-bukovih gozdovih na ravni gozdnogospodarske enote. Predstavljeni so kazalniki, ki bi jih lahko uporabili za ocenjevanje raznovrstnosti in ugodnega ohranitvenega stanja gozdnih habitatnih tipov na območjih Natura 2000. Na podlagi primerjave današnje in nekdanje sestojne zgradbe na 2 hektarskih raziskovalnih ploskvah je bilo mogoče oceniti razvojno dinamiko in spremembe strukturnih znakov gozdnih sestojev v zadnjih 50 letih. Na stalnih vzorčnih ploskvah smo uporabili kazalnike za ocenjevanje biotske in strukturne raznovrstnosti gozdnih sestojev na podlagi sestave drevesnih vrst, sestojnih gostot, povprečnih premerov in koeficientov variacije za premere dreves, Shannonovega indeksa za vrstno pestrost in debelinsko strukturo dreves, prostorsko razmestitev mešanosti in dominantnosti drevesnih vrst. S kazalniki smo potrdili razlike v zgradbi gozdnih sestojev štirih gozdnogospodarskih razredov, ki obsegajo raznodobne dinarske jelovo-bukove gozdove v Leskovi dolini na območju Snežniško-Javorniškega masiva. Stalne vzorčne ploskve in predstavljeni kazalniki sestojne zgradbe in raznovrstnosti bi lahko postali izhodišče za monitoring ugodnega ohranitvenega stanja gozdnih habitatnih tipov.

Ključne besede: sestojna zgradba, monitoring raznovrstnosti gozdnih sestojev, kazalniki, raznodobni jelovo-bukovi gozdovi, Abies alba Mill., Fagus sylvatica L.

UVOD
INTRODUCTION

The assessment of structural diversity of forest stands has been important in forest management for a long time - initially for predicting future stand growth, the resistance against storms, snow loads of stands and the effectiveness as a protection against other natural hazards. Stand diversity has become an important topic within the discussion of sustainability, biological diversity, namely alpha diversity that refers to the ecosystem diversity – the diversity within forest stands in forest ecosystems. Many authors have suggested and tested different measures of forest structural diversity, which can be characterized with respect to tree species diversity, tree size diversity and spatial diversity (Pommerening, 2002; Aguirre *et al.,* 2003; Varga *et al.,* 2005; McRoberts *et al.,* 2008). Cantarello and Newton (2008) suggested that the indicators of forest biodiversity, developed in order to support the assessment of sustainable forest management, may be of value for the assessment of the conservation status of forested habitats in the Natura 2000 sites. Forests represent more than a half of the Natura 2000 sites in the network representing one of the main actions for biodiversity conservation in Europe. In Slovenia, the Natura 2000 forest habitat types represent more than 260,000 ha of forests and it was estimated that the Natura 2000 sites encompass approximately one half of all the forests (Golob, 2006). Although the general guidance on the conservation status assessment has been provided (EC, 2005),

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a common standard for the implementation of monitoring of the Natura 2000 sites and forest habitat types has not yet been created (Cantarello and Newton, 2008).

In the large-area forest structural biodiversity assessments, the national forest inventories or other permanent monitoring plots (for example EU/ICP Forests programme) provide the most comprehensive and geographically extensive tree species and size diversity data. Unfortunately, the sampling intensity in regional inventories is typically too low and the plots are too small to adequately characterise individual stands (Koehl *et al.,* 1995). These data are not sufficient to determine the habitat and species diversity within landscape and forest compartment structures, or to investigate the causal factors such as land use change or forest management that affect the patterns of structural diversity and contribute to them. As proposed by Pommerening (2002), the quantification of stand structure has the advantage of being easier to survey by means of common forest inventories than more direct measures of diversity. Apart from using algorithms and concepts to relate the forest stand structure to the habitat functions, they can also be used to inform forest managers about the consequences of silvicultural activities. Even though the results presented in forest management plans provide us with important information on the effectiveness of silvicultural treatments, long term permanent observation is very important in order to understand the forest dynamics and to establish a monitoring strategy, appropriate for the assessment of the effectiveness of measures maintaining or improving a favourable conservation status of the forests.

In order to characterise the stand structure of forests, several parameters are needed. Forest scientists have developed a number of indices for quantification of different aspects of stand structure including small scale differences within stands. As has been shown by Fischer and Pommerening (2003), these indices require different data input, which can practically be provided by different inventory types. McElhinny *et al.* (2005) reviewed literature concerning forest and woodland structure at the scale of individual stands. As a group, the attributes identified describe stand structure in terms of foliage arrangement, canopy cover, tree diameter, tree height, tree spacing, tree species, stand biomass, understorey vegetation, and deadwood. The review indicates that there is no definite suite of structural attributes; different authors emphasised the subset of different attributes, and relatively few studies provided quantitative evidence linking attributes to the provision of faunal habitat or other measures of biodiversity, although a number of studies identified attributes that distinguish between successive stages.

Neumann and Starlinger (2001) used the data from permanent observation plots, established within the frame of the Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems, to quantify stand structure and species diversity by means of different indices (species richness, evenness, diversity, complexity, nonrandomness, clumping, aggregation, neighbouring pattern). Each of the plots where the mapping of the stands has been carried out comprised an area of 0.25 ha. A comparison of different indices has shown that there exist only few weak correlations between species diversity of different vegetation layers and between plant species diversity and the diversity of stand structure, while among all the indices of stand structure a correlation exists. Bachofen and Zingg (2001) have shown that even for the assessment of silvicultural treatment several parameters are needed. From the results of the first survey of subalpine Norway spruce forests they concluded that the variables *h/d* ratio, spatial distribution and the stand density index (SDI) were the best indicators of silvicultural treatments. They stressed that one survey is not sufficient to understand the forest dynamics; long-term permanent observation is very important and long-term commitments are needed.

Based on the review of scientific literature and recommendations of international research projects for monitoring forest biodiversity and sustainable forest management, Cantarello and Newton (2008) selected 17 indicators for monitoring the favourable conservation status of the forested habitats in the Natura 2000 sites. Most of these indicators were also harmonized by the representatives of the national forest inventories of 27 European countries and the USA participating in COST Action E43 »Harmonization of the National forest inventories in Europe« (Winter *et al.*, 2008). In this project, the biodiversity variables were ranked relative to their utility for the national forest inventory based biodiversity assessment. The most important and feasible variables were deadwood, stand-level development phases and forest types, horizontal and vertical structures, microsites, vegetation naturalness, tree age and diameter, abundance of old trees, species of trees and shrubs, variables related to forest management systems and disturbances. Similar to biodiversity and to sustainable forest management monitoring in the National forest inventories, the first reports of monitoring the conservation status of the habitats have been prepared at the national scale. The common standard for implementation of monitoring the Na-

tura 2000 sites and forest habitat types has not been created and the current results suggest that flexibility may be required to select the most appropriate indicators for individual sites (Cantarello and Newton, 2008). During the argumentation of financially acceptable indicators for the evaluation of the favourable conservation status of forest habitats it was estimated that the scientific literature does not yet provide information on the indicators usable in the monitoring of forest habitat types at the level of site or stand (Cantarello in Newton, 2008). Thus, the researchers determine the biodiversity and the condition of forest habitat types indirectly. During the process, the most frequently used key indicators at the level of forest stands were the following: number of trees (ha^{-1}), basal area of stands (m^2/ha), mean diameter of trees (cm), standard deviation of diameters and coefficient of variation (CV), Shannon's index for the assessment of tree species diversity and stand structural diversity, percentage of big trees in forest stands, mean height of trees (m), volume of snags and downed dead wood (m^3/ha).

The objective of this study was to test the proposed variables for describing forest structural diversity at the level of forest stands, based on the continuous forest inventory in forest management unit. We adopted the indicators for the assessment of stand structure diversity, developed within the framework of national forest inventories and forest monitoring projects in the European countries. The methods for characterisation of stand structure in the Dinaric fir-beech uneven-aged forests were used to assess to what extend were the data available within the Slovenian control sampling method suitable for calculating measures of stand diversity and differences between stand structures. We hypothesized that:

- permanent sample plots can be used for assessing the stands characteristics of forest habitat type at the local scale,
- the measurements of the stand diversity indicators vary between different forest management classes, which encompass forest management unit in the Dinaric fir-beech forests.

The objective did not include investigations of causal factors such as silvicultural measures or disturbances that affect stand structural diversity. The study examined the indicators that are expected to be used in the monitoring of biodiversity and the favourable conservation status of forest habitat types in Natura 2000 sites. Although it was estimated that most of the indicators relevant for the assessment of the conservation

status and monitoring are already in use in the forest management planning system in Slovenia (Golob, 2006), the reference values of stand structures and the variation within and between different indicators of forest stand structure were not tested in different forest habitat types as a part of proposed integral monitoring, incorporated into the planning process. The reference values from the investigations of stand structure performed up to now on research plots (Kotar, 2006; Hladnik and Skvarča, 2008) proved to be a good starting point for the assessment of forest habitat types and for the comparison with data and information gained through the continuous forest inventory in Slovenia. The research plots, established 60 years ago in the uneven-aged Dinaric beech-fir forest stands to study the optimal values of growing stock levels and the structure of forests, were used to estimate changes of stand diversity in periods of time, comparable with 10-year periods in forest management planning. The aim of this part of the study was to compare the indicators of stand structure diversity on the research plots in the past 50 years, during which the structure of the forests stands in the former selection forests has changed gradually.

MATERIALS AND METHODS
MATERIAL IN METODE

STUDY AREA AND DATA SOURCES
RAZISKOVALNO OBMOČJE IN VIRI PODATKOV

The indicators for the assessment of stand structures were tested in the Leskova valley, which represents a forest management unit and a part of Special Protection Area Snežnik-Pivka, included also in the habitat types of Illyrian beech forests. The forest management unit encompasses 3,011 ha of forests on the northeast slopes of the Dinaric mountain massive Snežnik. In Dinaric silver fir and beech forests on the high Karst with high diversity of natural conditions, uneven-aged forest stands are prevalent. They developed from a mature forest with old beech and silver fir trees and rich fir regeneration in the middle of the 19th century (Bončina *et al*., 2003). After the period of unsuppressed growth of fir and selection forest treatment, favouring selective harvesting of single trees or small groups of trees, the natural regeneration of fir was disturbed by red deer. These processes, the fir decline and uneven-aged forest management in the last 40 years have created a great variability of forest structures.

Table 1:   General characteristics of forest management classes in Dinaric fir-beech forests in Leskova valley (Forest management plan; Gozdnogospodarski načrt ..., 2007)

Preglednica 1: Osnovne značilnosti gozdnogospodarskih razredov jelovo-bukovih gozdov v Leskovi dolini (Gozdnogospodarski načrt ..., 2007)

Characteristics	*Omphalodo-Fagetum*			
	lycopodietosum	*homogynetosum*	*mercurialetosum*	*typicum*
Area (ha, percentage)	300.98 (10.0 %)	769.43 (25.6 %)	252.23 (8.4 %)	1120.82 (37.2 %)
Development phase or stand structure	Large timber 48.3 % Regeneration 41.9%	Uneven-aged 97.2 %	Uneven-aged 96.1 %	Uneven-aged 96.0 %
Average growing stock (m³/ha)	524	422	412	463
Percentage of growing stock by 20 cm DBH classes (%)	4 / 8 / 8 / 17 / 63	4 / 8 / 15 / 24 / 49	4 / 10 / 15 / 21 / 50	4 / 7 / 13 / 19 / 57
Annual volume increment (m³/ha)	11.2	8.4	8.3	9.8
Number of tree species	6	9	11	8
Number of sample plots	56	151	49	215

Stand diversity was assessed in four forest management classes, which encompass fir and beech forests in the altitude range between 750 and 1,250 m. These classes were named after the prevalent vegetation syntaxa of this part of Dinaric fir-beech forests: *Omphalodo- Fagetum* (Treg. 57) Mar et al. 93 (syn. *Abieti-Fagetum dinaricum* (Treg. 57) em. Punc. 79); *OF-typicum, OF-homogynetosum, OF-mercurialetosum, OF-Lycopodietosum* (Gozdnogospodarski načrt ..., 2007).

METHODS
METODE

The study includes 471 permanent sample plots on 250 x 200 m large systematic sampling grid, established by Slovenian Forest Service (Table 1). A permanent sample plot consists of two concentric plots of 200 m² and 500 m². All trees with the DBH of more than 10 cm were measured within the inner circular plot, whereas those with the DBH of more than 30 cm were measured within a circular plot of 500 m². The position of each tree on a sample plot was determined by the azimuth and the distance from the plot centre that enabled the calculation of indices of the spatial structure of trees in forest stands. Based on the concept of the tree factor or expansion factor, stand densities and stand diversity indices were calculated for sample plots, measured in 2003. In the same year, the measurement of trees on the research plots in Leskova valley and in a neighbouring forest management unit Mašun was finally repeated after 50 years of observations (Hladnik, 2004b). In 1950, 2-hectare-research plots were set up in silver fir and beech forests to study the optimal values of growing stock levels and the structure of selection forests on those plots.

The assessment of stand densities (the number of trees, the basal area, the stand volume) is one of the key elements in forest inventories and the data gathered on the sampling plots represent the basis for estimation of several indicators and proxy variables. On the permanent sampling plots, the statistic parameters are calculated based on the concept of the tree factor. Measurements on sample plots are summarized and expressed on a per unit area basis – per hectare for the metric system. The expansion factor referred to as the tree factor (Husch *et al*., 2003) was also suggested to harmonize the data from different sampling units in the COST Action E43.

The Shannon index (H') was intended for the assessment of species diversity, but it was used by many authors for the assessment of structural diversity of forest stands as well (Varga *et al*., 2005; McRoberts *et al*., 2008), with p_i representing the proportion of the basal area of trees in the DBH class compared with the total basal area:

$$H' = - \Sigma p_i \ln(p_i)$$

The coefficient of variation (CV) as a measure of differences between individual trees as regards their mean diameters was used to assess tree-size diversity in forest inventories or to estimate the structure of even-aged stands on the research plots (Kotar 1991, 2006). The reference values from previous researches of the stand structure in Slovenia are a good starting point for the assessment of forest habitat types and for the comparison with the data and information on the control sampling method in Slovenia. The methods for the assessment of the spatial structure of forest stands based on the coefficient of variation for the assessment of the spacing between the

trees have already been presented in the previous researches (Puhek, 1998; Hladnik, 2004a). However, on the permanent sampling plots it is possible to estimate the differences in the species structure and in the position of trees regarding the size of the neighbouring trees as well (Pommerening, 2002; Aguirre *et al.*, 2003). Aguirre *et al.* (2003) presented a method for comparing the spatial structure of different natural forest sites using a new approach for describing complex forest structures in a straightforward manner. They described the structure of forest stands by the spatial distribution of tree positions, by the spatial mingling of different tree species and by the spatial arrangement of tree dimensions, size differentiation and contagion. The spatial characteristics of stands have been established merely by evaluating the immediate neighbourhood of the given number of reference trees.

$$M_i = \frac{1}{4} \sum_{j=1}^{4} v_j$$

$$v_j = \begin{cases} 1, \text{neighbour } j \text{ belongs to the same species as reference tree } i \\ 0, \text{otherwise} \end{cases}$$

$$0 \le M_i \le 1$$

The parameters M_i (mingling) or U_i (differentiation) can have 5 values:

0.00 – all the neighbouring trees are of other tree species or are thicker than the reference tree,

0.25 – one of the neighbouring trees is of the same tree species or is thinner than the reference tree,

0.50 – two neighbours are of the same tree species or are thinner than the reference tree,

0.75 – three neighbours are of the same tree species as the reference tree,

1.00 – all five trees (the reference tree and the four neighbours) are of the same tree species or all four neighbouring trees are thinner than the reference tree.

On the sampling plots, the relations between the neighbouring trees with mean diameters of less than 30 cm, measured only on 200 m² subplots, could not be estimated in the same way as those between thicker trees, measured on the 500 m² plots. The radius of 7.98 m on the sampling plots was too small to enable the analysis of spatial arrangement for reference fir, beech and spruce trees and their 4 neighbouring trees within a 200 m² plot. The estimation of mingling distribution of thinner firs would be especially useful, since according to the forest management plan (Gozdnogospodarski načrt ..., 2007) it is necessary to support these firs and to

enable them the in-growth into the mature stands. However, a representative assessment could not be carried out, because the calculation could comprise only the data for the fir trees growing on less than a half of the sampling plots.

Statistical analyses and computing were performed using R (R Foundation for Statistical Computing). Descriptive statistics was employed in computing mean values, variances and standard errors. ANOVA was used in establishing differences between indices of species and DBH-based diversity for forest management classes. Frequency distributions of cut and survival trees by 20 cm DBH classes were compared using Brandt-Snedecor test for the 10- year periods of measurements on research plots. The present structure of forest stands in the area of four forest management classes was compared to the data of forest management plan from the year 1954. In this forest management plan, the data of total tallies of trees in forest compartments for individual tree species were shown for the first time. In the environment of geographic information systems (GIS), we were able to align the spatial data from old forest maps with present strata of forest management classes, owing the fact that the borders of forest departments remained unchanged and that at the level of forest compartments, only small changes were observed in the past as well.

RESULTS
REZULTATI

The three research plots represent a part of development processes taking place in fir and beech forests for the last 50 years and the share of starting points for the comparison with other fir and beech forests in this area. In the beginning of the observation period 55 years ago, the fir was prevalent in the majority of forest compartments encompassing four forest management classes of fir and beech forests in the area of the Leskova valley nowadays. Only in 4 of the 123 forest compartments, measured at that time with full callipering, the beech or the spruce was prevalent. In the group of compartments ranged nowadays in the forest management class *Omphalodo-Fagetum typicum*, the share of the fir on the basal area was 76%, in *OF-lycopodietosum* group 71%, in *OF-mercurialetosum* 96% and in *OF homogynetosum* 64%.

The values of the basal area of stands on the research plots were on the increase from the beginning of the 1970s onwards. In the ensuing period, characterized as the period of silver fir decline, however, the basal areas diminished until in the end of the 1980s the amount of firs in the basal area came to a stan-

Table 2:   Stand densities and diversity indices for three research plots in uneven-aged forest stands of fir and beech in
                 2003

*Preglednica 2: Sestojne gostote in kazalniki sestojne raznovrstnosti za tri raziskovalne ploskve v raznodobnih jelovo-bukovih
gozdovih v letu 2003*

Characteristics	Plot 97			Plot 98			Plot 99		
Number of trees (ha^{-1})	382			217			413		
Basal area (m²/ha)	49.4			38.1			48.9		
Growing stock (m³/ha)	718			571			700		
Big trees DBH>70 cm (% BA)	5			33			22		
Shannon index (H') based on									
5 cm classes	2.37			2.64			2.70		
20 cm classes	1.07			1.23			1.30		
species diversity	0.63			0.89			0.73		
Mean diameter	Fir	Spruce	Beech	Fir	Spruce	Beech	Fir	Spruce	Beech
Quadratic (cm)	37.2	45.0	19.8	54.8	37.6	42.2	44.6	40.3	24.6
Arithmetic (cm)	32.2	42.3	18.8	49.5	33.0	39.0	39.7	34.6	22.0
Coefficient of variation (DBH)	58	36	33	48	55	41	51	59	50

dstill or even increased (Fig. 1). In the course of development of stands, illustrated by quadratic mean changes, the beech gained significance on the plot 98. In 50 years, its share on the basal area has increased from 30% to 45%, whereas the share of the fir declined from 67% to 50%. On this research plot, the beech grew even into thicker DBH classes. In the year 1954, the share of the beech in the basal area of the DBH class of more than 50 cm was 8.6 %, while 50 years later it was 36.2%.

After 1971, the cutting of thinner trees in the lowest DBH class of 10-30 cm contributed to more significant changes of quadratic means of the fir, the beech and the spruce (Fig. 1). Especially noticeable are the changes of quadratic means of the beech and the spruce on the plot 98 after 1988. Using the Brandt-Snedecor test, we were able to confirm that after 1971 the frequency distributions of the cut trees typically differed from the distributions of other trees regarding the DBH classes. Until 1988, the cuttings of firs in the lowest DBH class (Plot 99, P<0.001; plot 97, P<0.05), spruce (Plot 97, P<0.001) and beech (Plot 98, P<0.05) were prevalent. During the regeneration of fir and beech forests, thinner trees did not preserve the role prescribed to them in the former selection forest treatment. In last decades, the recruitment rate of these trees into higher DBH classes has declined. Being of bad quality, the beeches in the lowest DBH class that used to be prevalent in the structure of the cutting on the plot 98 even after 1988 (P<0.001) were cut before the regeneration of stands. 86% of the beeches cut at that time were in the 10-30 cm DBH class.

On other research plots, the beech remained in the lower layer. On the plot dominated by the spruce (Plot 97), the be-

ech did not overgrow the quadratic mean of 50 cm, while on the plot 99 its share in this DBH class declined from 4.5% in the year 1951 to 2.3% fifty years later. On both research plots, the share of the fir in the stand basal area declined by 5% in a period of 50 years. After the last measurements in 2003, the regeneration of stands has begun in the area of the research plots as well.

On the permanent sampling plots measured in the year 2003, the prevalent share of the fir could still be estimated in the stand basal area of four forest management classes (Fig. 2). Its share declined most visibly in the forest management class *OF-lycopodietosum* (24%) on account of the share of the spruce in the stand basal area that was estimated to be two times bigger than 50 years ago. In other forest management classes, the average value of fir basal area was greater than the basal area of other tree species (P<0,001), although until the year 2003, the share of the spruce increased also in *OF-homogynetosum* class (by 9%), in *OF- mercurialetosum* (7%) and in *OF- typicum* (6%). The share of the beech in the stand basal area of uneven-aged stands increased most significantly (by 9%) in the forest management class *OF- typicum*.

The differences between the stands were estimated indirectly, based on the quadratic means of individual tree species and on the coefficients of variation for these means. Our estimations have shown that while the average diameters of the fir are at the biggest, its coefficients of variation are at the smallest, which confirms its dominant position in the present stands in four forest management classes of fir and beech forests. The fir prevails in the stand basal area of the thickest
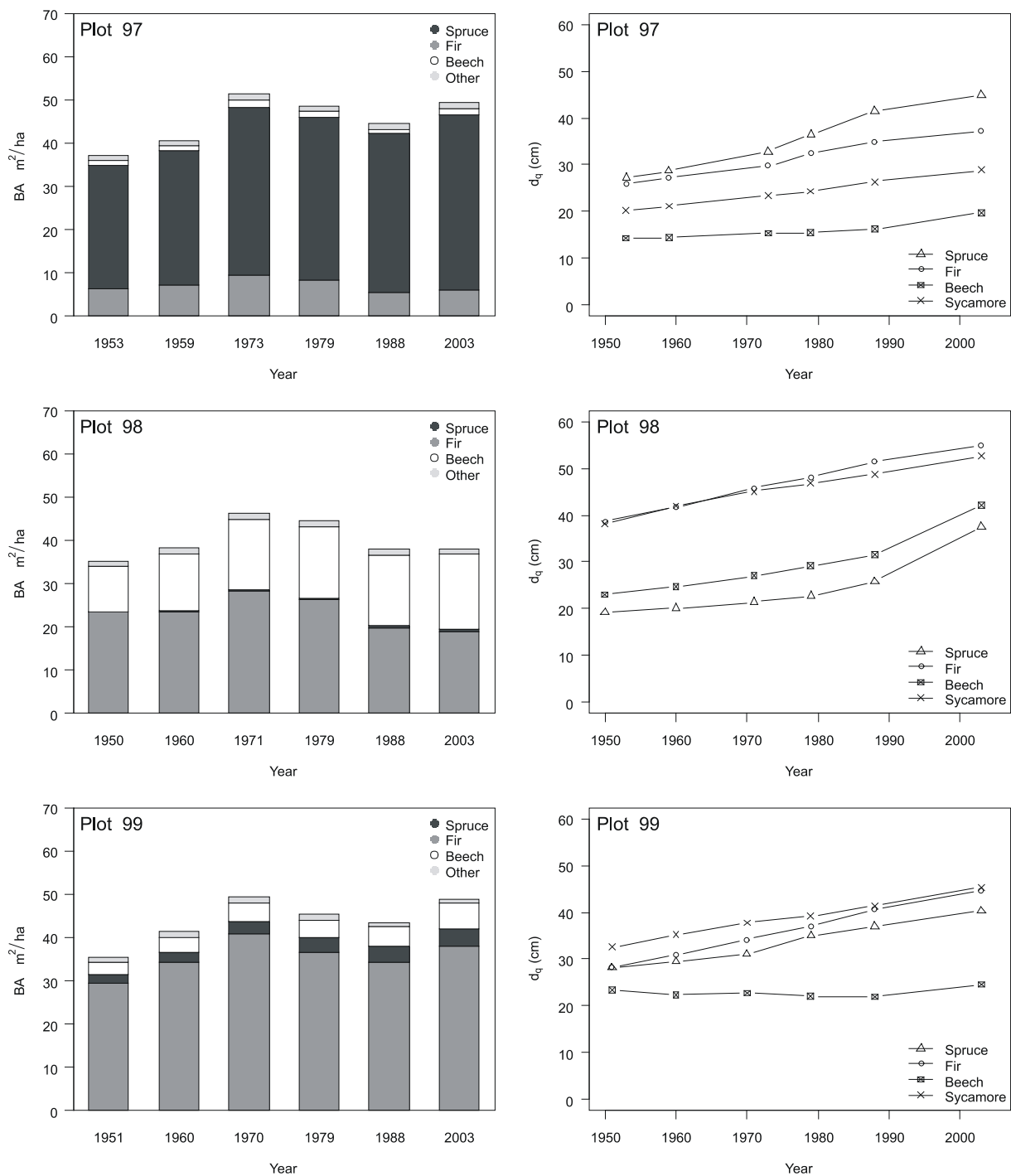
Fig. 1:   The changes in the structure of basal area and the development of the quadratic means of trees on three research plots in Dinaric fir-beech forests from 1950 to 2003

Slika 1:   Spremembe v strukturi temeljnice in razvoj srednjetemeljničnih premerov dreves na treh raziskovalnih ploskvah v dinarskih jelovo-bukovih gozdovih od leta 1950 do 2003

trees, however, its share in the DBH class to 30 cm is smaller compared to the beech and the spruce (Fig. 3).

On the basis of 500 m^2 sampling plots we estimated the diversity of DBH-based structure in the fir and beech forest stands. Since the sampling plots are too small to enable such estimations, we confirmed a high level of variability in the stand structure indirectly, based on the coefficients of varia-

tion arithmetic mean diameters of the spruce, the fir and the beech. On individual sampling plots, the groups of tree species representing uniform stand structures were present rather rarely. Only on one fifth of the sampling plots, the coefficients of variation for arithmetic diameters of the fir, the spruce and the beech were estimated to be smaller than 20%. Even in the forest management class *OF-lycopodietosum*, dominated
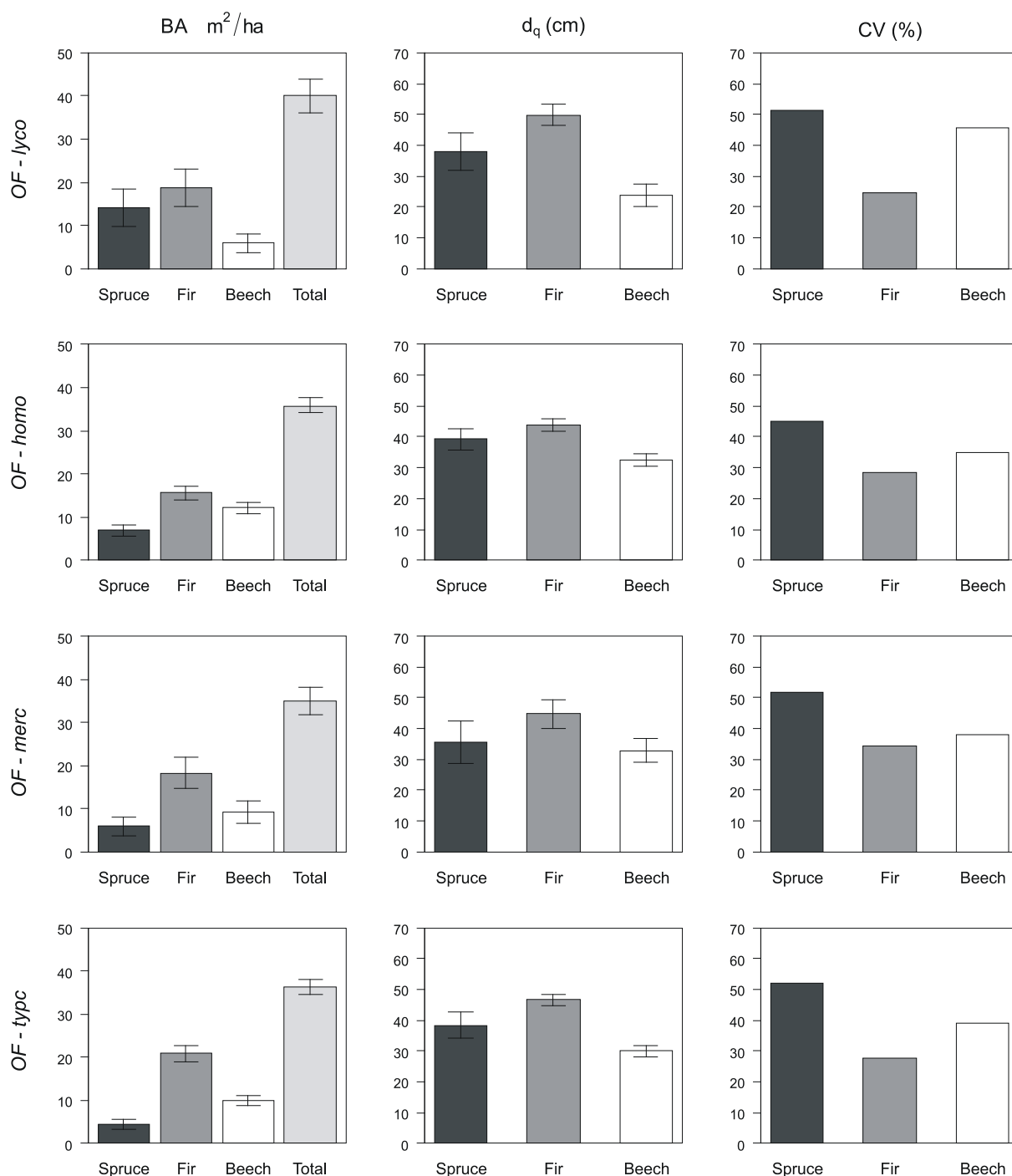
Fig. 2: The estimations of the basal area, quadratic means and coefficients of variation for average diameters on the permanent sampling plots in the fir-beech forests of the Leskova valley in 2003

Slika 2: Ocene temeljnice, srednjetemeljničnih premerov in koeficientov variacije za povprečne premere na stalnih vzorčnih ploskvah v jelovo-bukovih gozdovih Leskove doline v letu 2003

according to data in the forest management plan (Gozdnogospodarski načrt …, 2007) by uniform fir and spruce stands with mixed deciduous trees, the coefficients of variation for arithmetic mean diameters were estimated to be smaller than 20% merely on 17% of the sampling plots. In the distribution of the coefficients of variation in Figure 4, the medians of

the spruce and the beech were equal (CV = 37%), while the median of the fir was at 38%.

The diversity of stand structure in the fir-beech forests was confirmed on the basis of the DBH-based Shannon index as well (Fig. 5). On 2-hectare-research plots, the DBH-based Shannon indices have increased and reached the highest value when the trees were represented in all 4 DBH classes. In
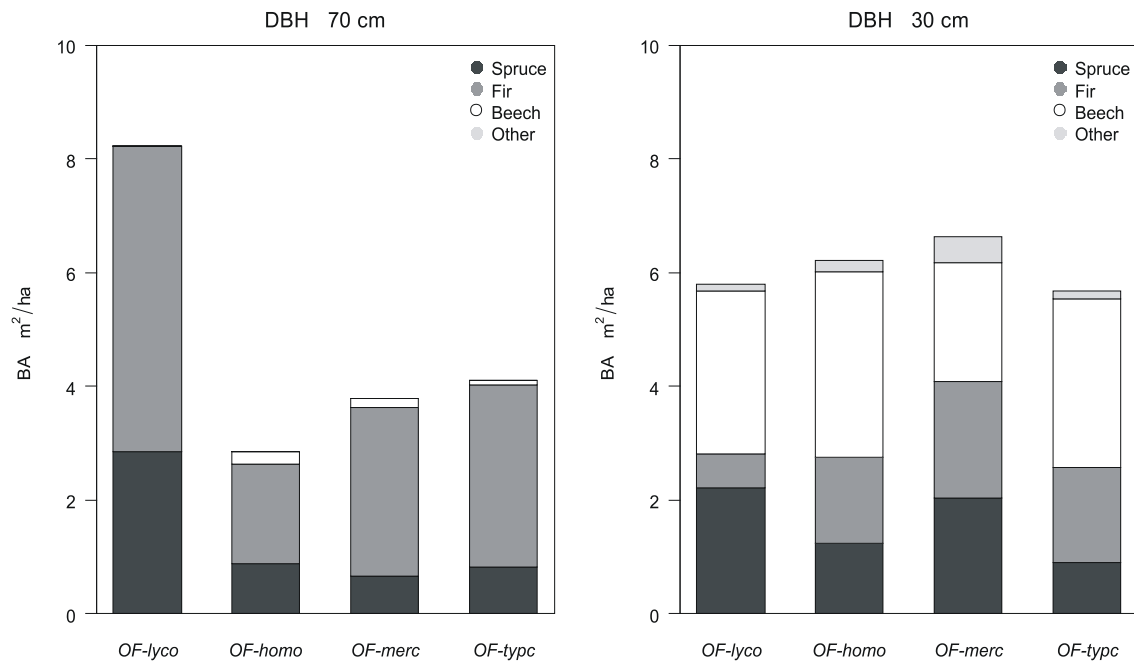
Fig. 3: The basal areas of tree species for the highest and the lowest DBH class in the fir- beech forest of the Leskova valley, estimated on the permanent sampling plots in 2003

Slika 3: Temeljnice drevesnih vrst za največji in najmanjši debelinski razred v jelovo-bukovih gozdovih Leskove doline, ocenjene na stalnih vzorčnih ploskvah leta 2003
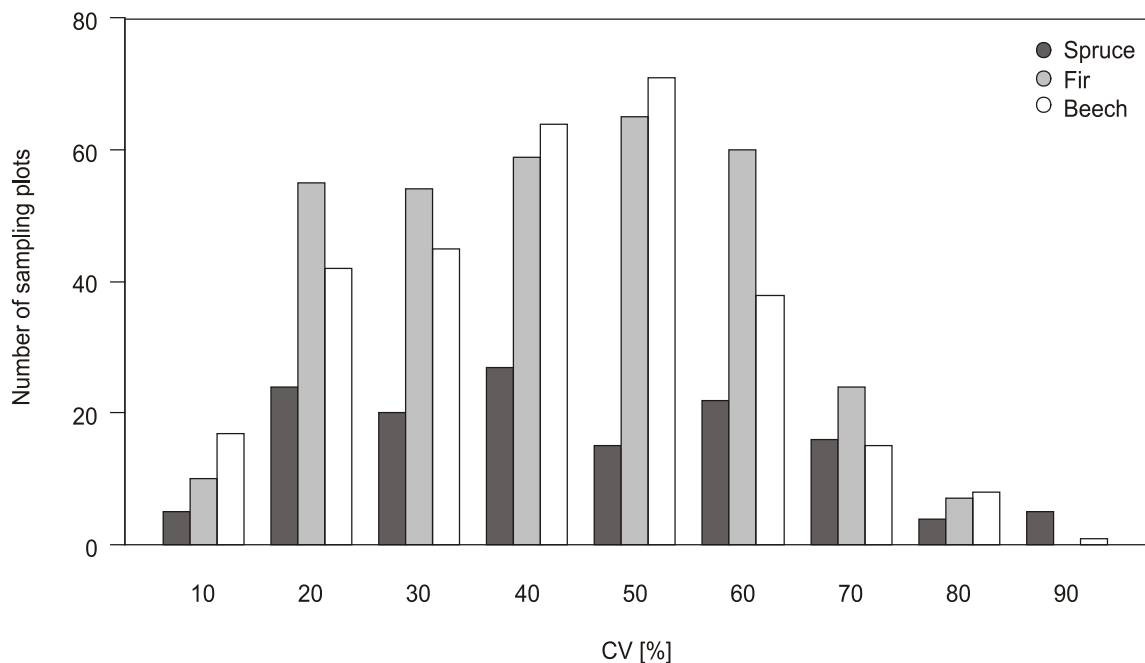

Fig. 4: Frequency distribution of permanent sampling plots according to CV classes, calculated for arithmetic means of silver fir, beech and Norway spruce in fir-beech forest in the Leskova valley in 2003

Slika 4: Frekvenčna porazdelitev števila vzorčnih ploskev po posameznih razredih koeficientov variacije, ki so bili izračunani za aritmetično srednje premere treh drevesnih vrst v jelovo-bukovih gozdovih Leskove doline leta 2003

the year 2003, the Shannon index reached 94% of maximum values for 5 cm and 20 cm DBH classes on the plot with prevalent fir (Plot 99). The index was the lowest on the plot with prevalent spruce (Plot 97), where it had reached 90% of the highest value for 5 cm classes and 70% for 20 cm classes. The latest measurements on the research plots have estimated lower Shannon's indices for 5 cm and 20 cm DBH classes on the plot 98, since the trees have grown into higher DBH
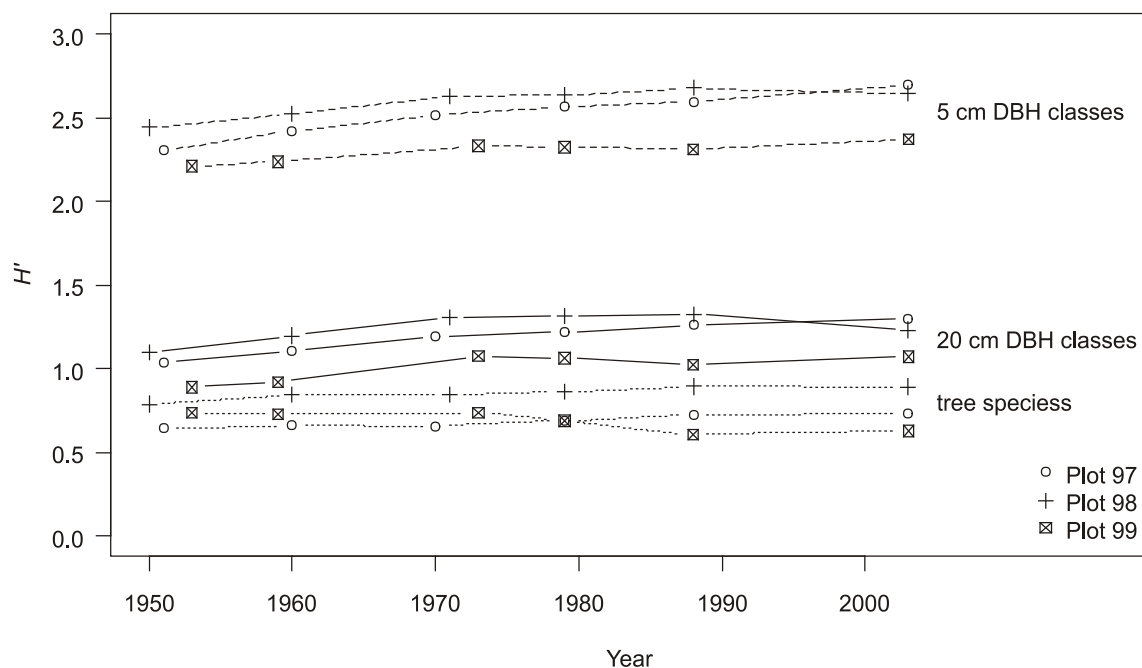
Fig 5: Changes of DBH-based Shannon's index for 5 and 20 cm classes and species based index on tree research plots in Dinaric fir-beech forest between 1950 and 2003

Slika 5: Spremembe Shannonovih indeksov za debelinsko pestrost po 5 cm in 20 cm debelinskih razredih ter indeks vrstne pestrosti na treh raziskovalnih ploskvah v dinarskih jelovo-bukovih gozdovih v med letoma 1950 in 2003

classes and the share of the basal area in lower DBH classes has declined. This estimation is confirmed also by the coefficient of variation for mean diameter of trees that has declined from 58% to 46% since the year 1988. As regards the fir, the coefficient of variation remained the same as in the previous period, while that of the spruce diminished by 7% and of the beech by 12% on this research plot.

The Shannon index of species diversity on the research and permanent sampling plots was the lowest among three comparative indices, because the major part of the basal area was dominated by two tree species, whereas on the plot with prevailing spruce, the Shannon index of species diversity grew even smaller after the year 1970. The shares of the fir, beech and sycamore *Acer pseudoplatanus* in the stand basal
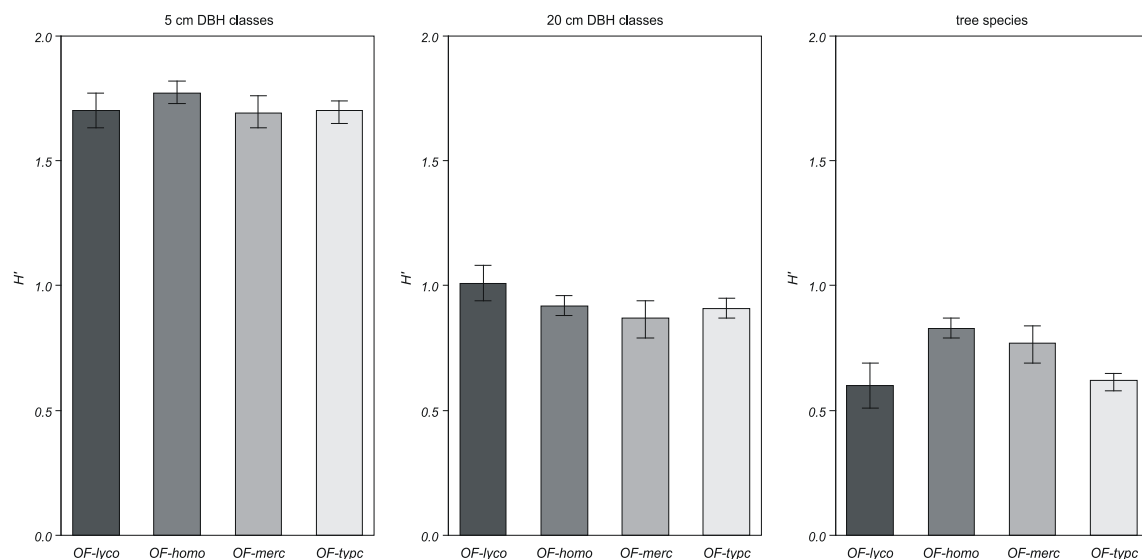

Fig. 6: Shannon's indices for DBH and species diversity, estimated on the permanent sampling plots in 4 forest management classes in 2003

Slika 6: Shannonovi indeksi za debelinsko in vrstno pestrost, ocenjeni na stalnih vzorčnih ploskvah v 4 gozdnogospodarskih razredih leta 2003
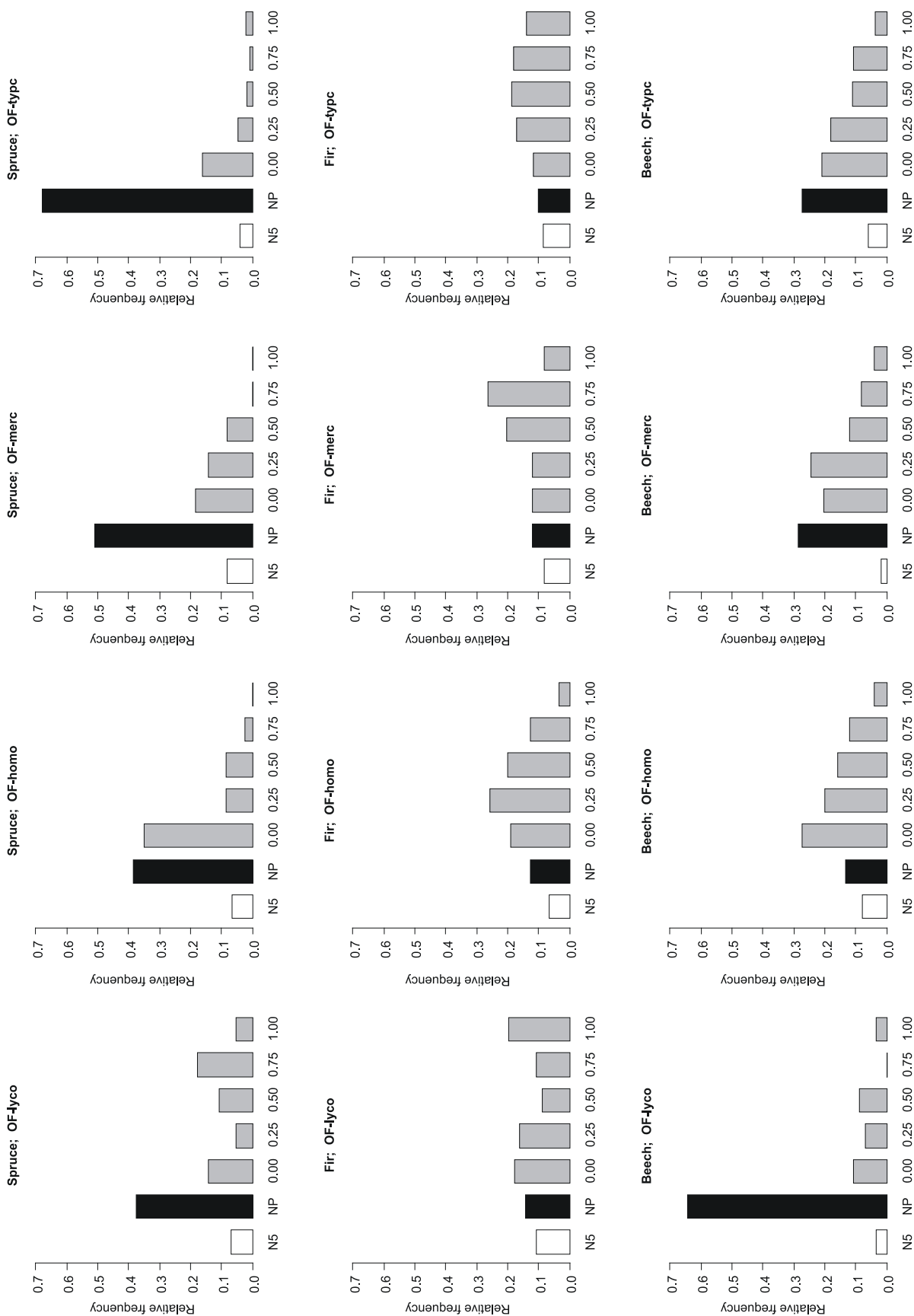
Fig 7: Species-specific mingling distribution for three tree species in four forest management classes in the Leskova valley, based on permanent sampling plots in 2003 (for trees with DBH ≥ 30 cm, NP – species was not present on the sampling plot, N5 – less than 5 trees on the sampling plot)

Slika 7: *Porazdelitev ocen za prostorsko razmestitev mešanosti treh drevesnih vrst v štirih gozdnogospodarskih razredih v Leskovi dolini na podlagi stalnih vzorčnih ploskev iz leta 2003 (drevesa s premerom d$_{1,3}$≥ 30 cm, NP – drevesne vrste ni bilo na vzorčni ploskvi, N5 – na vzorčni ploskvi je bilo manj kot 5 dreves)*
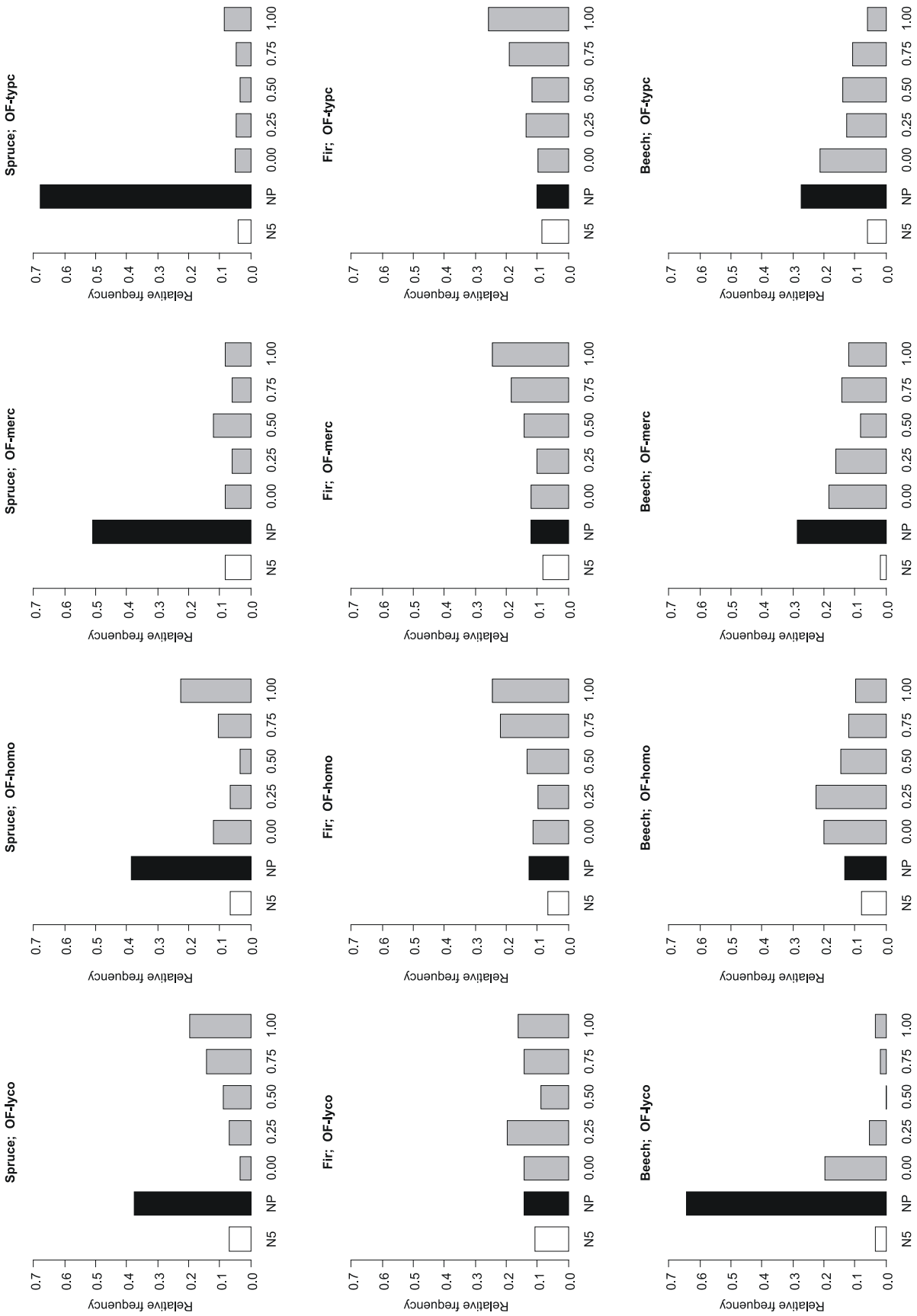
Fig 8:   Species-specific dominance distribution for three tree species in four forest management classes in the Leskova valley, based on permanent sampling plots in 2003 (for trees with DBH ≥ 30 cm)

Slika 8:   Porazdelitev ocen za dominantnost treh drevesnih vrst v štirih gozdnogospodarskih razredih v Leskovi dolini na podlagi stalnih vzorčnih ploskev iz leta 2003 (drevesa s premerom $d_{1,3} \geq 30$ cm)

area of this plot declined after the year 1973, which is indicated also by slower growth of quadratic means of these tree species in comparison with the pine. Since 1988, however, the value of the Shannon index for the estimation of species diversity on the research plots with prevailing spruce has not been on the decline any longer.

In the forest management class *OF-homogynetosum*, the greatest DBH-based structure diversity in 5 cm DBH classes as well as the greatest species diversity were assessed (P<0.05). Furthermore, a big share of thick trees in the forest management class *OF-lycopodietosum* (Fig. 3) confirms the Shannon index for 20 cm DBH classes (Fig. 6), which differed significantly from the indices in other three forest management classes (P<0.05).

Due to the fact that the share of the fir in the basal area of forest stands has diminished, while at the same time the trees were in the process of growing into higher DBH classes, we have estimated the position of these trees on permanent sampling plots. In the year 2003, the fir remained prevalent on 46% of the sampling plots in the forest management class *OF- lycopodietosum*, on 49% of the plots in the class *OF-homogynetosum*, on 65% in OF *mercurialetosum* and on 63% of the plots in the class *OF- typicum* regarding the basal area of sampling plots. The fir was not present only on 12% of the sampling plots. In addition to its significant share in the basal area of the thickest trees, the fir was prevalent also in the groups of trees thicker than 30 cm, which were used for the estimation of the relations between neighbouring trees on the 5-are-sampling plots (Figs. 7 and 8).

Mingling distribution and species-specific dominance distribution represent the diversity of stand structure and confirm previous assessments of the prevalent position of the fir and of the differences in species structure between 4 forest management classes. In the forest management plan (Gozdnogospodarski načrt ..., 2007), the forest management class *OF–homogynetosum* was assessed according to its tree structure as one of the best preserved in the area of the Leskova valley. Our estimations have shown that on the sampling plots in this class, the fir is present in smaller groups of trees as in other forest management classes. Furthermore, it is frequently mingled with the beech (present on 87% of the sampling plots) and with the spruce (present on 55% of the sampling plots). The spruce was often admixed singularly (Fig. 7), however, among the trees on the 500 m² plots, it took the role of the dominant tree most frequently (Fig. 8).

The spruce was the most significantly present in the forest management class *OF- lycopodietosum*, where on the sampling plots, the groups of up to 4 spruce trees were prevalent and could most frequently be found among the dominant trees. Based on the estimated relations between the neighbouring trees, the beech in the DBH class of more than 30 cm was assessed to gain significance on the sampling plots most frequently singularly or in a group of two trees. The plots where the beech prevailed in the stand basal area or in groups of three or more trees represented 26% of the total number of sampling plots in 2003.

DISCUSSION
RAZPRAVA

The aim of the present study was to test the variables expected to be used for describing forest structural diversity at the level of forest stands and monitoring the favourable conservation status of forest habitat types in Natura 2000 sites. The research plots in the area of the forests of Snežnik have already been presented in the previous researches into the structure and development of uneven-aged stands in former selection forests of fir and beech (Tregubov, 1957; Čokl, 1961; Hladnik 2004b). This time, three research plots were used in order to illustrate structural changes and stand diversity in uneven-aged fir and beech stands. The research plots cannot be seen as representative of individual vegetation syntaxa or stand types; however, they represent the characteristics of stands that have achieved the greatest density in the course of their development and were chosen as an example of optimum stand types in the area of fir and beech Snežnik forests 60 year ago (Tregubov, 1957).

In the course of their development, the stands on the research plots 97 and 99 provided growing stock comparable to the final growing stock on the sites, evaluated in the optimum models of the Slovenian forests (Veselič, 2002). Our estimations during the time of the greatest stand densities have shown that the values of growing stock of the stand on the plot 98 with prevailing fir and beech were by 11% lower than the model values in the sites of fir and beech forests on deep soils. On the permanent sampling plots measured in 2003, the basal areas on 14% of the plots were estimated to be larger than 50 m²/ha and thus comparable to the ones on the research plots. Similar results based on continuous forest inventory have been shown in the old growth forests Krokar and Rajhenavski Rog in the Dinaric fir-beech forests of the Kočevje region (Pisek, 2010) and in earlier survey of the structure of these

virgin forests (Bončina, 1997). In the neighbouring managed forests, the stand basal area was at 58% to 67% of the basal area in comparable old growth forests (Pisek, 2010).

In the previous researches of changes in tree species composition and forest structure during the last century, the data from old forest management plans and forestry archives were used at the level of forest compartments (Bončina *et al*., 2003; Kogovšek, 2008); however, on the basis of aggregated data it was not possible to estimate the level of structural and species diversity of forest stands, comprised in forest management departments and compartments. Regardless of the forestry archives, research plots were set up 60 years ago in order to enable the research of stand development in fir and beech forests (Tregubov, 1957). For that purpose, the areas of significant and economically important forest communities were chosen to study the stand types in uneven-aged and selection forests. Based on the first resumed measurements, it was estimated that the growing stock and increments on these plots had exceeded the values in other management forests considerably (Čokl, 1961).

On the research plots, the treatment history and the development processes within forest stand were monitored, but these plots are not representative of the total forest population, especially in uneven-aged forest with great variability of forest structures. Koehl *et al*. (1995) demonstrated some limitations on both permanent sample plots from forest inventories and experimental growth and yield study plots in Switzerland. They stressed that in regional inventories, sampling intensity is typically too low and the plots are too small to adequately characterise individual stands, moreover, the history treatment cannot be deduced from the data assessed on the plots. On the other hand, growth and yield plots are not applicable to all conditions encountered in forest surveys - low value species, non-fully stocked conditions, uneven-aged and mixed stands are underrepresented. By linking both types of plots, it is possible to improve both forest surveys and growth and yield studies.

In Slovenia, the growth and yield studies based on experimental plots comparable to the researches carried out in many other European countries as regards the extent and continuity have not been arranged and maintained (Marell and Leitgeb, 2005), nor has the work on the research plots been finished in a way that would enable us to use them as reliable reference values in forest management or even as one of the starting points for the assessment of the development of stands in different forest habitat types in Slovenia (Hladnik in Skvar-

ča, 2008). The monitoring of forest habitat types in Natura 2000 sites in Slovenia can be seen as part of forest inventory and observation of forest development in forest management planning, since in the whole area of Slovene forests, forest management and silvicultural planning is carried out. The indicators of structural diversity are indirectly comprised in the concept of forest planning, the aim of which is to preserve and to shape the natural forest stands and the exploitation of forested sites in accordance with natural developments of forest associations (Pravilnik …, 1998). For the comparison of the conservation status of forest habitat types with other European countries, the indicators derived from the data of forest inventory that were otherwise intended for the assessment of forest areas and for the estimation of their structure will be of the greatest significance. These indicators are presented in the article, however, we did not specifically analyze the indicators that have already been included into forest management plans (Table 1) or presented in the detailed survey of dead wood amount and structure for the phytogeographic regions and forest sites of Slovenia (Poljanšek, 2008) .

The prevalent sampling grid in Slovenian forest inventory extends over 250 x 250 m and 500 x 250 m (Matijašić in Medved, 2008). The sampling intensity is too low to characterise individual stands, but it enables estimations of stand structures and their changes at the level of individual strata – forest management classes. These classes were chosen as the starting point for the definition of forest habitat types in the potential Natura 2000 sites. Forest habitat types were determined on the basis of forest associations and preservation of the species composition. Furthermore, they are represented within forest management classes that comprise forests of similar ecological characteristics (Golob, 2006). Golob (2003) stated that managing of the Natura 2000 sites does not differ substantially from close to nature forest management. The favourable conservation status of forest habitat types would be ensured with aims and directives in forest management plans. Moreover, the plans should examine not only the forest sustainability, but also the conservation status of habitat types and species. However, for this kind of examination it is necessary to define what conservation condition of habitat types could still be considered as favourable.

As an expedient for continuous forest management, optimum models of forest, designed as the ideal forest condition, constantly ensuring the provision of its functions, were designed (Veselič, 2002). Golob (2003) estimated these models to be insufficient for the assessment of conservation status of

forest habitat types at the level of forest management classes, due to the fact that they include only tree species composition and forest structure. Similarly, the single indicators on which the assessment of the favourable conservation status was supposed to be carried out are not sufficient. The DBH-based Shannon index reaches the highest values, if the proportions of the basal area are equal in all DBH classes. If we assessed the diversity based on this index, we would stipulate the same starting point as determined in the instructions for the arrangement of selection forests in the area of Snežnik from the year 1906 (Dolgan, 1957; Čokl, 1957). In a regular selection forest, the DBH classes of equal widths were expected to have equal values of basal areas or growing stocks as well. In recent researches of selection forest structure it was estimated (Kotar, 2006) that theoretic distributions of trees by DBH classes are not a necessary condition for a balanced state in these forests. In primeval beech and fir forests, typical selection stand structures appear relatively infrequently and are not naturally sustainable in the long run (Schuetz, 2001).

Shannon's indices based on species and DBH-based structure diversity differ between four forest management classes in the analysed forest management unit (Fig. 6). These results indicate that quantitative assessment of forest structure can be achieved using standard forest inventory methods, enabling comparisons to be made within forest habitat types and to estimate changes in periods of time, comparable with 10-year periods in forest management planning. The variables of spatial mingling and size differentiation provide further information about the differences of stand features and developmental trends for the different forest management classes.

Nowadays, it is difficult to define the favourable conservation status in uneven-aged silver fir and beech forests. Based on the development of these forests up until now, the preservation status cannot be defined merely as a static model of tree species composition, size and DBH based structure of growing stock in these forests. The alternation of fir and beech has been observed in long-term research sites in managed forests and virgin forest remnants. Based on increment analyses, it was shown that the current population of silver fir regenerated in a short period of time in the beginning of the 19th century in the former beech-dominated forests (Gašperšič, 1967; Bončina *et al*., 2003). The share of conifers increased until 1974, but the share of silver fir in small diameter classes decreased during the period of ageing process and decline of the silver fir population. Today, the silver fir in Slovenia is still in decline (Ficko and Bončina, 2006).

In the area of four forest management classes in Leskova valley, the silver fir is still preserved and prevalent in forest stands. For the future development of forest stands, its regeneration is crucial. Our estimations based on permanent sample plots have shown that nowadays silver fir prevails in the stand basal area of the thickest trees, but its share is smaller in DBH class of less than 30 cm (Fig. 3). On special plots, where the damage of saplings is estimated, the share of fir saplings was at 10%, in the forests of four forest management classes in the Leskova valley, presented in this article, however, the share of fir saplings in young growth was only at 5% (Gozdnogospodarski načrt…, 2007). Similar conditions prevail in other forests of the habitat type of Illyrian beech forests in Slovenia. Roe deer and red deer browsing was declared the main problem of sustainable forest management in Dinaric fir-beech forests as their population can significantly influence the process of natural regeneration in forest stands. The comparison of vegetation in fenced and unfenced areas has shown that natural regeneration of Dinaric fir-beech forests is successful if the influence of ungulates is excluded (Jarni *et al*., 2004).

In the Dinaric mountain forests, intensive in-growth of beech into the canopy can be observed and all indices suggest that the fir will decline further in the future (Bončina *et al*., 2003). The silver fir decline was observed in old-growth forests in Dinaric mountains of Slovenia and Croatia (Diaci *et al*., 2007). The investigations of long-term changes in tree species composition suggest that management was not the predominant factor in replacing silver fir with beech. The causes for silver fir decline might include the pollution of ecosystems, climate change, high densities of the ungulates and non-adapted silvicultural systems to the silver fir ecology.

The monitoring process carried out as part of the Natura 2000 network is only a continuation of previous work, in which the forest monitoring based on continuous forest inventory was included as part of forest management planning. Continuous forest inventory may in future become the basis for the monitoring of the favourable conservation status of forest habitat types, their changes and development trends. However, further work is needed to evaluate the potential of methods and data gathered by means of forest inventory in the assessment of the relation of forest structure and composition to the provision of habitat for individual species. It was estimated that forest biodiversity indicators developed for the assessment of sustainable forest management may potentially be of value for monitoring the favourable conservation status of forested habitats in the Natura 2000 sites (Cantarello and

Newton, 2008). However, a level of uncertainty as to which indicators should be used in order to determine all the aspects of the favourable conservation status still remains.

POVZETEK

Pri gospodarjenju z gozdovi je bilo ocenjevanje strukturne raznovrstnosti gozdnih sestojev na Slovenskem vgrajeno v proces gozdnogospodarskega in gozdnogojitvenega načrtovanja, v zadnjih desetletjih pa je postalo pomembno tudi v sklopu mednarodnega monitoringa trajnostnega gospodarjenja z gozdovi in njihove biotske raznovrstnosti. Na regionalnih in velikopovršinskih ravneh je tak monitoring zajet v nacionalnih gozdnih inventurah in zlasti v sklopu kontrolne vzorčne metode na podlagi stalnih vzorčnih ploskev. V gozdarstvu na Slovenskem so bile stalne vzorčne ploskve najpogosteje postavljene na vzorčnih mrežah gostote 250 x 250 m in 500 x 250 m (Matijašić in Medved, 2008), kar zagotavlja ocenjevanje sestojnih značilnosti in zgradbe na ravni rastiščnogojitvenih tipov oziroma gozdnogospodarskih razredov. Kazalniki za ocenjevanje sestojne raznovrstnosti bodo najverjetneje v večini evropskih držav uporabljeni tudi za ocenjevanje ohranitvenega stanja gozdnih habitatnih tipov v sklopu omrežja Natura 2000 (Cantarello in Newton, 2008). V gozdnogospodarski enoti Leskova dolina, ki obsega raznodobne dinarske jelovo-bukove gozdove, uvrščene v gozdni habitatni tip ilirskih bukovih gozdov območij Natura 2000, smo kazalnike prikazali za štiri gozdnogospodarske razrede jelovo-bukovih gozdov, da bi preverili morebitne razlike v njihovi sestojni raznovrstnosti.

Na podlagi treh raziskovalnih ploskev, velikih 2 ha, smo ocenili kazalnike sestojne raznovrstnosti in njihove spremembe v jelovo-bukovih sestojih v zadnjih 50 letih (preglednica 1, sliki 1 in 2). Raziskovalnih ploskev ne moremo sprejeti kot reprezentativne za posamezne gozdne združbe ali sestojne tipe, ponazarjajo pa značilnosti sestojev, ki so v svojem razvoju dosegli najvišje gostote in so bili pred 60 leti izbrani kot primer optimalnih sestojnih tipov na območju snežniških jelovo-bukovih gozdov (Tregubov, 1957). Na začetku opazovanega obdobja je jelka prevladovala v večini odsekov, ki obsegajo današnje štiri gozdnogospodarske razrede jelovo-bukovih gozdov na območju Leskove doline. Na stalnih vzorčnih ploskvah, ki so bile izmerjene leta 2003, smo še ocenili prevladujoč delež jelke v sestojni temeljnici štirih gozdnogospodarskih razredov. Njen delež se je zmanjšal najmočneje v gospodarskem razredu *OF- lycopodietosum* (24 %) na račun

smreke, za katero smo ocenili dvakrat večji delež v sestojni temeljnici kot pred 50 leti. V drugih gozdnogospodarskih razredih je bila povprečna vrednost temeljnice jelke večja od temeljnice drugih drevesnih vrst (P<0,001), čeprav sta se deleža smreke in bukve v sestojni temeljnici povečala do 10 %.

Za jelko smo ob najvišjih povprečnih premerih ocenili najmanjše koeficiente variacije, kar potrjuje njen dominantni položaj v današnjih sestojih v štirih gozdnogospodarskih razredih jelovo-bukovih gozdov. Prevladovala je v sestojni temeljnici najdebelejšega drevja, v debelinskem razredu do 30 cm pa je bil njen delež v primerjavi z bukvijo in smreko manjši (slika 3). Na podlagi koeficientov variacije za aritmetično srednje premere smreke, jelke in bukve smo potrdili veliko variabilnost v sestojni zgradbi. Na posameznih vzorčnih ploskvah so bile le redko zajete skupine drevesnih vrst, ki bi ponazarjale enomerne sestojne strukture. Na 5-arskih vzorčnih ploskvah smo ocenili nižje vrednosti Shannonovega indeksa za debelinsko pestrost kot na 2-ha raziskovalnih ploskvah, primerljiva pa so bila razmerja med posameznimi indeksi. V gospodarskem razredu *OF- homogynetosum* je bila ob najvišji oceni za pestrost debelinske strukture v 5 cm debelinskih razredih ocenjena tudi najvišja vrstna pestrost (P<0,05). Visoki delež debelega drevja v gospodarskem razredu *OF-lycopodietosum* (Slika 3) potrjuje tudi Shannonov indeks za 20 cm debelinske razrede (slika 6), ki se je značilno razlikoval od indeksov v preostalih treh gozdnogospodarskih razredih (P<0,05). Veliko sestojno raznovrstnost in prevladujoči položaj jelke smo potrdili tudi na podlagi ocen o prostorski razmestitvi mešanosti drevesnih vrst in njihove dominantnosti v sestojni strehi štirih gozdnogospodarskih razredov (sliki 7 in 8). V gozdnogospodarskem načrtu (2007) je bil gozdnogospodarski razred *OF-homogynetosum* po drevesni sestavi ocenjen kot eden najbolj ohranjenih na območju Leskove doline. Na vzorčnih ploskvah v tem razredu smo ocenili, da se jelka pojavlja v manjših skupinah dreves kot v drugih gozdnogospodarskih razredih. Močneje sta ji primešana bukev, zajeta na 87 % vzorčnih ploskev, in smreka na 55 % vzorčnih ploskev. Smreka je bila najpogosteje primešana posamič, toda med drevesi na 5-arskih ploskvah je najpogosteje zastopala dominantna drevesa. Na podlagi ocenjenih sosedskih odnosov smo ocenili, da se je bukev v debelinskem razredu nad 30 cm na vzorčnih ploskvah najpogosteje uveljavila posamič ali v skupini dveh dreves. Ploskve, kjer je bukev prevladovala v sestojni temeljnici oziroma v skupinah treh ali več dreves, so v letu 2003 sestavljale četrtino skupnega števila vzorčnih ploskev.

Na območju štirih gozdnogospodarskih razredov v analizirani gospodarski enoti je jelka še ohranjena in prevladuje v gozdnih sestojih. Za prihodnji razvoj gozdnih sestojev je odločilno njeno pomlajevanje. Pri pomlajevanju in obnovi jelovo-bukovih gozdov razvojno mlajše jelke niso ohranile vloge, ki jim je bila pripisana v prejšnjem prebiralnem gospodarjenju, in tudi danes je v gozdnogospodarskem načrtu (2007) predpisano, da je treba take jelke pospeševati in jim omogočiti vrast v odrasle sestoje. Preraščanje jelke po debelinskih stopnjah je v zadnjih desetletjih upadalo (Hladnik, 2004a), o zmanjševanju deleža jelke pa so poročali tudi na širšem območju dinarskih jelovo-bukovih gozdov na Slovenskem in Hrvaškem (Diaci *et al.* 2007). Na podlagi dosedanjega razvoja teh gozdov ohranitveno stanje v gozdnih habitatnih tipih ne more biti opredeljeno zgolj kot statičen model drevesne sestave, velikosti in debelinske strukture lesnih zalog v teh gozdovih. Monitoring v sklopu Natura 2000 je le nadaljevanje dosedanjega dela, v katerem je bilo ocenjevanje razvojnih procesov v teh gozdovih del gozdnogospodarskega načrtovanja. Gozdno inventuro in predstavljene kazalnike sestojne raznovrstnosti bi lahko uporabili za ocenjevanje stanja in sprememb v gozdnih habitatnih tipih območij Natura 2000, v nadaljnjem raziskovanju pa je treba oceniti njihovo morebitno primernost in učinkovitost pri presojanju o ohranitvenem stanju posameznih vrst in njihovih habitatov.

ZAHVALA

REFERENCES

Aguirre, O., Hui, G., Gadow, K.v., Jimenez, J. 2003. An analysis of spatial forest structure using neighbourhood-based variables. Forest Ecology and Management, 183, 137–145.

Bachofen, H., Zingg, A., 2001. Effectiveness of structure improvement thinning on stand structure in subalpine Norway spruce stands. Forest Ecology and Management, 145, 137–149.

Bončina, A., 1997. Naravne strukture gozda in njihove funkcije v sonaravnem gospodarjenju z gozdom. Doktorska disertacija. Ljubljana, Univerza v Ljubljani, BF, 210 s.

Bončina, A., Gašperšič, F., Diaci, J., 2003. Long-term changes in tree species composition in the Dinaric mountain forests of Slovenia. Forestry chronicle, 79, 2, 227−232.

Cantarello, E., Newton, A.C., 2008. Identifying cost-effective indicators to assess the conservation status of forested habitats in Natura 2000 sites. Forest Ecology and Management, 256, 815–826.

Čokl, M., 1957. Kritični pregled metod za urejanje snežniških gozdov. Ljubljana, IGLG, Strokovna in znanstvena dela, 4, 107–118.

Čokl, M., 1961. Raziskovalne ploskve v prebiralnih gozdovih na Snežniku v razdobju 1949-1960. Ljubljana, IGLG, 92 s.

Dolgan, F., 1957. urejanje gozdov na področju Snežnika s posebnim ozirom na revir Leskova dolina. Ljubljana, IGLG, Strokovna in znanstvena dela, 4, 85–106.

Diaci, J., Roženbergar, D., Mikac, S., Anić, I., Hartman, T., Bončina, A., 2007. Long-term changes in tree species composition in old-growth Dinaric beech-fir forest. Glasnik za šumske pokuse, 42, 13–27.

EC, 2005. Note to the Habitat Committee, Assessment, monitoring and reporting of conservation status – Preparing the 2001-2007 report under Article 17 of the Habitats Directive. European Commission, DG Environment, Nature and Biodiversity, Brussels.

Ficko, A., Bončina, A., 2006. Silver fir distribution in Slovenian forests. Zbornik gozdarstva in lesarstva 79, 19–35.

Fischer, R., Pommerening, A., 2003. Methodology for stand structure assessments in the biodiversity test phase 2003-2005 of EU/ICP Forests. Working group on Biodiversity Assessment in Forests, ICP on Assessment and Monitoring of Air Pollution Effects on Forests, 11 pp.

Gašperšič, F., 1967. Razvojna dinamika mešanih gozdov jelke-bukve na Snežniku v zadnjih sto letih. Gozdarski vestnik, 7–8, 202-237.

Golob, A., 2003. Gozdnogospodarski načrti in ohranjanje biotske pestrosti gozdov Slovenije v luči pravnega reda Evropske unije. V: Bončina, A. (Ur.). Območni gozdnogospodarski načrti in razvojne perspektive slovenskega gozdarstva. Ljubljana, Biotehniška fakulteta, Oddelek za gozdarstvo, 209−225.

Golob, A., 2006. Izhodišča za monitoring ohranjenosti gozdnih habitatnih tipov in habitatov vrst na območjih Natura 2000 v Sloveniji. V: Hladnik, D. (Ur.). Monitoring gospodarjenja z gozdom in gozdnato krajino. Ljubljana, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, str. 223–245.

Gozdnogospodarski načrt za GGE Leskova dolina 1955–1964. 1955. Postojna, Gozdno gospodarstvo Postojna.

Gozdnogospodarski načrt za GGE Leskova dolina 2004–2013. 2007. Postojna, ZGS – OE Postojna.

Hladnik, D., 2004a. Ocenjevanje prostorske zgradbe jelovo-bukovih sestojev. Zbornik gozdarstva in lesarstva, 74, 165−186.

Hladnik, D., 2004b. Debela drevesa v jelovo-bukovih gozdovih na visokem krasu. V: Brus, R. (Ur.). Staro in debelo drevje v gozdu. Zbornik referatov študijskih dni. Ljubljana, Univerza v Ljubljani, BF, Oddelek za gozdarstvo in obnovljive gozdne vire, str. 151–166.

Hladnik, D., Skvarča, A., 2008. Gozdarske raziskovalne ploskve in stalne vzorčne ploskve na območjih Natura 2000 na Slovenskem. Gozdarski vestnik, 67, 1, 3−52.

Husch, B., Beers, T.W., Kershaw, J.A., 2003. Forest Mensuration. 4th ed. Wiley, Hoboken, New Jersey.

Jarni, K., Robič, D., Bončina, A., 2004. Analysis of the influence of ungulates on the regeneration of dinaric fir-beech forests in the research site Trnovec in the Kočevje forest management region. Zbornik gozdarstva in lesarstva, 74, 141−164.

Koehl, M., Scott, C.T., Zingg, A., 1995. Evaluation of permanent sample surveys for growth and yield studies: a Swiss example. Forest Ecology and Management, 71, 187−194.

Kogovšek, T., 2008. Razvoj gozdov v gozdnogospodarski enoti Leskova dolina. Diplomsko delo. Ljubljana, Univerza v Ljubljani, BF, 75 s.

Kotar, M., 1991. Zgradba bukovih sestojev v njihovi optimalni razvojni fazi. Zbornik gozdarstva in lesarstva, 38, 15−40.

Kotar, M., 2006. Zgradba, rast in donos gozda na ekoloških in fizioloških osnovah. Ljubljana, Zveza gozdarskih društev Slovenije, Zavod za gozdove Slovenije, 500 s.

Marell, A., Leitgeb, E., 2005. Field research and monitoring of Europe's forests: a historical perspective. European long-term research for sustainable forestry: Experimental and monitoring assets at the ecosystem and landscape level. Technical Report 3, COST Action E25, 1−35.

Matijašič, D., Medved, M., 2008. Spremljanje poseka pri gospodarjenju z gozdovi. Gozdarski vestnik, 66, 1, 49−64.

McElhinny, C., Gibbons, P., Brack, C., Bauhus, J., 2005. Forest and woodland stand structural complexity: Its definition and measurement. Forest Ecology and Management, 218, 1−24.

McRoberts, R.E., Winter, S., Chirici, G., Hauk, E., Pelz, D.R., Moser, W.K., Hatfield, M.A., 2008. Large–scale spatial patterns of forest structural diversity. Canadian Journal of Forest Research, 38, 429−438.

Neuman, M., Starlinger, F., 2001. The significance of different indices for stand structure and diversity in forests. Forest Ecology and Management, 145, 91−106.

Pisek, R., 2010. Vpliv strukturnih posebnosti sestojev v gozdnih rezervatih na razvoj monitoringa gozdnih ekosistemov. Magistrsko delo. Ljubljana, Univerza v Ljubljani, BF, (v tisku).

Poljanšek, S., 2008. Količina in struktura odmrlega drevja v gozdovih Slovenije. Diplomsko delo. Ljubljana, Univerza v Ljubljani, BF, 45 s.

Pommerening, A., 2002. Approaches to quantifying forest structures. Forestry, 75, 305−324.

Pravilnik o gozdnogospodarskih in gozdnogojitvenih načrtih. Uradni list RS, št. 5/1998.

Puhek, V., 1998. Procjena strukturnih elemenata sastojine na osnovu prostornog rasporeda stabala. Zagreb, Sveučilište u Zagrebu, Šumarski fakultet, 194 s.

Schuetz, J-P., 2001. Opportunities and strategies of transforming regular forests to irregular forests. Forest Ecology and Management, 151, 87−94.

Tregubov, V., 1957. Prebiralni gozdovi na Snežniku. Vegetacijska in gozdnogospodarska monografija. Ljubljana, IGLG, Strokovna in znanstvena dela, 4, 163 s.

Varga, P., Chen Han, Y.H., Klinka, K. 2005. Tree-size diversity between single and mixed species stands in three forest types in western Canada. Canadian Journal of Forest Research, 35, 593−601.

Veselič, Ž., 2002. Optimalni modeli gozdov. Strokovna izhodišča in način oblikovanja modelov ob izdelavi gozdnogospodarskih načrtov območij za obdobje 2001-2010. Gozdarski vestnik, 60, 10, 445−460.

Winter, S., Chirici, G., McRoberts, R.E., Hauk, E., Tomppo, E., 2008. Possibilities for harmonizing national forest inventory data for use in forest biodiversity assessments. Forestry, 81, 1, 33–44.